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ABSTRACT

Within the Apollo Program, there is a need to receive, store, and analyze data about the lunar environment. The need arises from the responsibility to ensure that the knowledge of the moon is fully utilized in Apollo tests, operations, astronaut training, and site selection.

This paper is a broad outline of the problem, listing data inputs, data outputs, and rough definitions of a series of tasks. It is recognized that further definition is necessary for tasks and data outputs.

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SUBJECT: Apollo Lunar Data Analysis - Case 211

DATE: July 19, 1965

FROM: C. J. Byrne

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TECHNICAL MEMORANDUM

I. INTRODUCTION

There is a need for the Apollo Program to receive, store, and analyze data about the lunar environment. The purpose is to ensure that our knowledge of the moon is fully utilized in Apollo tests, operations, astronaut training, and site selection. This paper is a preliminary definition of the work to be done.

The scope of application of this paper is restricted to data analysis in support of planning for the early Apollo missions. It does not cover analysis of data for specific scientific purposes, nor does it cover data analysis for environmental studies in space.

In principle, plans for data analysis should keep in step with project plans, even in very early stages. However, this paper does not consider specific data analysis tasks for programs under advanced study, nor does it consider proposal of new data-gathering projects.

A. Earth-Based Programs

1. telescopic photography
   primary control network
   lunar atlas
2. visual observation
3. photometric, spectral, and polarization surveys
4. radar reflection surveys
5. thermal emissivity surveys
6. simulation of hypothetical lunar materials
7. geological classification

[redacted]

B. Unmanned Lunar Probes

1. Ranger
   photography
   trajectory

2. Surveyor
   photography
   landing dynamics
   tactile measurements
   chemical analysis
   landing radar
   trajectory
   micrometeoroid measurements
   seismic detection
   thermal sensors
   rocket exhaust effects

3. Lunar Orbiter
   photography
   high resolution
   low resolution stereo
   trajectory

4. Interplanetary Monitoring Probes D and E (Lunar Anchored IMP's)
   radar reflection survey
   trajectory

II. DATA OUTPUTS

A complete listing and specification of useful data outputs should be generated by the appropriate groups within the Apollo Program. The following is a preliminary listing presented in order to stimulate discussion.

A. Site Selection and Site Survey Planning

1. landing quality terrain maps

2. low resolution photomosaics

3. low resolution stereo pairs

4. high resolution photographs, appropriately indexed to the low resolution photomosaics

5. control maps and/or charts

6. geological maps

7. maps of variations in the electromagnetic reflection and emission properties

B. Simulation Aids

1. soil model
   theoretical description
   simulation materials

2. small-scale relief model
   computer data
   physical model

3. visual model

4. radar reflectivity model

5. thermal emission model

C. Operational Aids

1. charts for use in approach and in orbit

2. charts for use in descent and landing

3. charts for surface operations

4. gravitational field description

5. descent altitude profile

6. navigational landmarks

III. DATA ANALYSIS TASKS

In broad terms, the data analysis function is to convert the output data from a number of independent programs into a unified body of knowledge in appropriate format for the Apollo program. The job may be seen as three separate tasks: research and study to determine methods for analysis of anticipated data and existing information, large volume data processing, and production, indexing and storage of outputs.

A. Research and Study Tasks

Wherever possible, these tasks should be based upon the existing lunar information, including earth-based and Ranger data.

1. Landing Quality Definition:

   The properties of the Apollo landing gear and nominal operational plans should be studied in relation to known and postulated properties of the lunar surface in order to determine the measurements needed to estimate landing quality of a lunar site.

2. Soil Mechanics Research:

   Tests should be performed with a simulated LEM landing gear to determine the nature of the LEM-soil interaction, applicable methods of measuring soil properties, and the effects on soil of high vacuum and meteoroid bombardment.

3. Terrain Quantification:

   Methods of characterizing lunar terrain in terms of landing quality should be studied. Emphasis should be placed on using known properties of the lunar surface.

4. Quality Definition of Maps and Charts:

   A study should be performed to establish the map scales and types of data presentations most useful to Apollo.

5. Image Analysis Research:

   Studies should be made of automated scanning of lunar photographs to characterize the terrain in terms of roughness, slope, material, possible subsurface structure, etc. Conversion of images to topographic displays through photometry and photogrammetry should be studied. Direct characterization of the images and processing of the images to enhance critical patterns should also be considered. Further study of the lunar photometric function should be pursued.

6. Geological Research:

Geological research on the nature of the lunar surface, classification of features, formation and modification processes, and correlation of features and properties should be encouraged for the insight offered to the methods of data analysis.

B. Large-Volume Data Analysis

The effort required to translate the raw data into usable form can be broken down into the following tasks:

Correct for instrument calibration.

Convert data from measured parameters to parameters of interest to the Apollo Program.

Evaluate the data in the context of all other available knowledge.

Accordingly, some of the tasks below are associated with specific projects, while others are grouped under the title "Combined Data Analysis". The tasks require careful attention to details of instrument design and a high degree of scientific analysis. The level of the work should be of high quality since the problem is one of interpreting data about unknown phenomena. Even such an apparently simple task as preparation of the photographs becomes complex when the problems of stereo viewing, cross-indexing, and display are considered.

1. Analysis of Surveyor Data

The purpose of Surveyor large volume data analysis is to provide a detailed description of a few small areas. The description may be used for Apollo operations if the area is chosen as a landing site, or may be used for interpretation of data from other programs.

a. Landing dynamics

Accelerometer, rate-gyro, strain gauge, and shock absorber displacement data should be

converted to motions and forces of the pads during landing. A phenomenological study should be undertaken in an attempt to separate force components due to soil compression, shear failure, sliding friction, plowing, and obstacle encounter.

b. Soil mechanics

Visual and force information from the soil sampler, rocket exhaust, and TV survey should be combined with the landing dynamics data to predict a suitable theoretical soil model for the LEM. The data should be compared with similiar information taken from tests of sample materials on earth. In lieu of multiple soil mechanics measurements, the TV survey data should be analyzed to determine the visual homogeneity of the surface.

c. Television survey

The television data should be reduced to a detailed description of the local topography and surface texture. It may be desirable to build a full scale or reduced scale model of the area for test purpose. The local photometric function should be derived and visual displays generated for simulating the Apollo approach.

d. Chemical analysis

The alpha particle scatter data should be analyzed. The result should be related to the soil mechanics work and information from the visual survey, thermal sensors, etc. Correlation with similar data from natural and artificial terrestrial materials should be attempted.

2. Analysis of Lunar Orbiter Data

The Lunar Orbiter data analysis task is characterized by the large amount of data. Each Lunar Orbiter produces one million times more non-redundant high resolution data than a Ranger spacecraft. Sophisticated methods of high-speed data processing are essential.

a. Photographic processing

In its primary form, Lunar Orbiter data is recorded on 35 mm film. Sub-frames (9 x 14 inch size) are reassembled from the 35 mm film. Further processing should be performed to produce formats more suitable for photo interpretation. Facilities should be provided to aid photo interpretation. The following specific tasks should be covered:

Large area, low resolution controlled photomosaics should be assembled and displayed. The scale and coordinates should be consistent with standard maps. Rectification of the sub-frames may be required.

A minimal set of stereo pairs should be selected and indexed to the photomosaics. Lens and readout distortion should be corrected if possible. A stereo viewing facility should be provided.

An indexed file of high resolution photographs should be established. Optical dodging, noise suppression, detail enhancement, and other optical techniques should be applied to maximize the usefulness of these photos.

b. Digital data processing

The lack of strong variations in albedo (normalized brightness) and the special photometric function of the Moon make the lunar photographs suitable for automatic processing. Data will probably be available on magnetic tape as well as on photographic film. The steps involved are:

Conversion of selected data to digital form

Calibration correction and image enhancement

Slope and profile control derived from stereo photos

Conversion from brightness to topography

Study is needed to define the exact methods to be used. With further understanding of the lunar terrain, short cuts may be possible.

c. Priority assignment

Visual examination and possible rough computer processing should be used to determine the order of thorough processing for site survey planning and site selection.

3. Analysis of Earth-Based Data

The large variety and volume of data being collected through NASA-funded programs of earth-based measurements of lunar surface properties will contribute substantially to our knowledge of the entire Apollo area of interest. The data will be gathered through many techniques, including radar, radiometry, photometry, and geologic inference.

The capability of these programs to make definitive statements about properties of the lunar surface which are critical to the Apollo Program is presently limited, but their information will be made much more valuable when correlated with information from Surveyor, Lunar Orbiter, and Apollo itself. A considerable amount of integration will be necessary in order that these various programs can contribute to a unified description of the Apollo area of interest. Specific tasks include:

a. Conversion to common format

Digital representation for computer processing.

Maps consistent with a single base display (for example, the ACIC LAC Charts).

b. Derivation of special parameters

Soil density inferred from radar data.

Surface roughness inferred from radar data.

4. Combined Data Analysis

The processed data from all sources should be combined to ensure that full advantage is taken of cross-correlation and mutual calibration of data from diverse sources. The aim should be to compensate for shortcomings in one type of data with information from an independent source. There are three distinct tasks in combined data analysis:

a. Data correlation

The various types of broad area data should be cross-correlated with each other. Areas showing high mutual correlation among several properties should be mapped.

b. Landing quality analysis

The soil mechanics information from Surveyor analyses and the topographic data derived from Lunar Orbiter should be combined with the knowledge of Apollo capability and the understanding gained from study of earth-based, Ranger, and IMP data. The end result should be a set of terrain maps representing relative landing quality ratings and geological descriptions of areas examined by lunar probes.

c. Extrapolation of landing quality

Estimates of landing quality outside the area directly examined can be made by correlation of direct measurements in limited areas with data over the entire area of interest taken by earth-based survey.

IV. OUTPUT PRODUCTION

The final data should be presented in convenient form for use. Many forms will be needed, for example:

Maps and charts.
  Earth use.
  Astronaut use.
Three-dimensional models at various scales.

Visual displays.
Documents describing the data.
Specification of simulated soil materials.

Description of most of the outputs must await further study.

V. SCHEDULE

The first Surveyor data may be available in the fall of 1965. The first Orbiter data may be available in the summer of 1966. Each program launches at a rate of once every three months. There is no restriction on relative phasing at this time.

VI. FUTURE PROGRAMS

It is expected that future programs, including the Apollo program itself, will provide further lunar data for analysis. Plans for data analysis should parallel project plans in the study phase to insure timely preparation and convenient data formats.

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